R | Soils and Geology Discipline Report

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SR 502 CORRIDOR WIDENING

IMPROVING SAFETY • INCREASING CAPACITY • REDUCING CONGESTION

I-5 TO BATTLE GROUND

FINAL

Soils and Geology Discipline Report

Prepared for:

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This project is also referred to as "SR 502/I-5 to Battle Ground – Add Lanes".

Errata Sheet

Soils and Geology Discipline Report

November 2009	Throughout: The "Mill Creek North potential mitigation site" was selected as a mitigation site and purchased by Washington State Department of Transportation (WSDOT) in 2009, therefore the name of this site is now the "Mill Creek North mitigation site."

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Executive Summary

The purpose of this Executive Summary is to summarize the findings of the Final Soils and Geology Discipline Report for the SR 502 Corridor Widening Project.

What studies, methods, and coordination were used to identify existing soils and geology in the study area?

Information for this report was obtained from several governmental agencies, in the form of reports, maps, and web-based resources. A WSDOT Geotechnical Engineering Memo which contained records of soil borings, laboratory testing, and geotechnical design guidelines was also reviewed. Additionally, field reconnaissance and site visits aided in the preparation of the report. No subsurface investigations were conducted as part of this study.

What is a geologic hazard?
A geologic condition or phenomenon that presents a risk or potential danger to life or property. Geologic hazards may be naturally occurring (earthquakes, volcanic eruptions) or man-made (subsidence due to construction activities).

How were effects to soils and geology determined?

Potential geologic hazards were first identified by reviewing geologic and soils related maps, reports, and databases developed by Clark County, the State of Washington Department of Natural Resources, and the United States Geological Survey. Potential hazards were also identified from site reconnaissance and from technical memoranda. Once the potential hazards were identified, they were compared with the conditions present in the study area to determine the effects. The study area for this report is defined as the area within unincorporated Clark County along SR 502 beginning at NE 15th Avenue and continuing east to NE 102nd Avenue. The study area is 200 feet north and south from the centerline of the roadway. The Mill Creek North potential mitigation site was included in the study area. A second area, the Sunset Oaks wetland mitigation site was also studied. Hazards that initiate outside of the study area, such as volcanic eruptions and earthquakes, were included in this report.

How is volcanic rock formed?
Volcanic rocks are formed from cooling lava that is either ejected explosively or flows from a volcano.

How is marine sedimentary rock formed?
Marine sedimentary rock forms from soils (sediments) that were once on the ocean floor and consolidated into rock.

What are the existing soils and geology conditions in the study area?

Geology

The study area lies within the Portland Basin, a geologic depression that was formed by volcanic and marine sedimentary rocks. Overlying these rocks are soils that were deposited from the ancient

Columbia River. These soils are moderately consolidated sandy gravel. Additional soils have been deposited in the study area as a result of enormous floods which took place as recently as 13,000 years ago. These floods resulted from massive ice dam failures in western Montana, which sent water and debris coursing down the Columbia River and deposited sandy soil in the project area.

Soils

There are ten soil types within the study area, eight of which intersect the current alignment (see sidebar). Five of these soils are considered prime farmland and two would be prime farmland if drained. Prime farmland is highly productive cropland that is protected by the U.S. Department of Agriculture's Natural Resources Conservation Service. One of the soils, Tisch silt loam, is highly organic and may contain deposits of peat. Organic and peaty soils contain large amounts of decomposed plant matter and may settle excessively if built on.

The Sunset Oaks wetland mitigation site contains seven soil types (see sidebar). Two of these soils are considered prime farmland, two would be prime farmland if drained, one would be prime farmland if irrigated, and two are not considered to be prime farmland.

What temporary effects to soils and geology would occur?

During construction, ground clearing activities will take place which could allow soils to erode. Soil loss from erosion could negatively affect surface water resources and associated habitat. Soils exposed to windblown erosion could create nuisance dust, which may reduce visibility, create respiratory hazards, cover adjacent fragile agriculture, and may harm visual quality by getting in the way of views and creating dusty conditions.

What long-term effects to soils and geology would occur?

Differing Subsurface Conditions

If soils are not characterized correctly, embankments and roadways could settle excessively. This could result in breaks in utilities, deformed culverts that do not function properly, or deformed roadways that are unpleasant or unsafe to drive on.

Soil Types within Study Area

- Gee silt loam*1
- Odne silt loam*
- Hesson clay loam*1
- Washougal gravely loam*1
- Tisch silt loam*2
- Lauren loam*1
- Dollar loam*1
- Hockinson loam, moderately well drained*2
- Olequa silty clay loam
- Cove silty clay loam

* Soil types intersect alignment
1 Prime farmland
2 Prime farmland if drained

Soil Types within the Sunset Oaks wetland mitigation site

- Cove silty clay loam
- Cove silty clay loam, thin solum
- Hillsboro silt loam, 0 to 3% slopes1
- Hillsboro silt loam, 3 to 8% slopes1
- McBee silt loam2
- Semiahmoo muck2
- Sifton gravelly loam3

1 Prime farmland
2 Prime farmland if drained
3 Prime farmland if irrigated

Poor Bearing Capacity

Soils may be encountered that have poor bearing capacity and are unsuitable subgrade material when saturated due to high groundwater or wet weather working conditions. The effects to the Build Alternative if this is encountered could include bearing failure, excessive settlement, and poor pavement performance.

Liquefaction

Liquefaction is a process in which water-saturated soil temporarily loses its strength and acts as a fluid. This can happen during an earthquake. Liquefaction can lead to settlement, damage structures, and cause embankment failures.

Prime Farmland

As currently designed, approximately 12 to 16 acres of prime agricultural soils would be converted to non-agricultural uses. This will result in a loss of agricultural capacity in the study area. This estimate does not include land that would be used for stormwater detention outside of the right of way or mitigation sites. The reader should refer to the *Final Land Use/Agriculture and Farmland/ Public Lands/Relocations and Right of Way Acquisitions Discipline Report* (Parsons Brinckerfoff, 2008a) for further information on prime farmland.

What would be the effects to soils and geology if the project is not built?

Under the No Build Alternative, continued use of the existing SR 502 facility and surrounding land would occur. No soils would be disturbed and no prime farmland would be converted to non-agricultural uses as a result of this project.

What measures are proposed to minimize or avoid negative effects to soils and geology?

Negative effects would be minimized by following the WSDOT Geotechnical Design Manual during the subsurface investigation and design of project facilities. A geotechnical evaluation will be performed to obtain sufficient information concerning potential geologic and soil hazards.

Effects related to soil erosion would be minimized through best management practices during construction. The construction contractor would be required to prepare and implement plans to

What is erosion?
Erosion is the wearing away of soil and rock. This may be by weathering and the action of streams, glaciers, waves, wind, and underground water.

What is prime farmland?
Prime farmland is soil that is highly productive and protected by the U.S. Department of Agriculture's Natural Resources Conservation Service.

What are best management practices?
Best management practices are used to reduce and prevent erosion during construction. Examples of best management practices include scheduling construction activities to minimize exposed soil areas, preservation of as much existing vegetation as possible, and dust control by applying water to exposed soils.

ment dust control during construction.

Following completion of the project, WSDOT maintenance procedures for the new facility should be followed to ensure continued minimal effects from geologic hazards.

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List of Exhibits

1.0 Introduction

The SR 502 Corridor Widening Project is located in north Clark County, Washington along SR 502 (NE 219th Street) between NE 15th Avenue and NE 102nd Avenue. The western terminus of the study area is approximately one mile east of Interstate 5 (I-5) and the eastern terminus is NE 102nd Avenue. The project would widen an approximate five mile segment of SR 502 from two travel lanes to four travel lanes and upgrade several intersections to improve mobility and safety. Currently, SR 502 is a rural, two-lane highway. There is one signalized intersection at SR 502 and NE 72nd Avenue. For a more detailed description of the project, see the separate *Revised Description of Alternatives* document (Parsons Brinckerhoff, 2008c).

The purpose of this document is to describe the existing soils and geology conditions, discuss effects and benefits the project would have on soils and geology, and identify mitigation measures to address adverse effects as needed. The information contained in this discipline report will be used to support the project's Environmental Impact Statement (EIS).

2.0 Studies, Coordination, and Methods

Information used in this study was obtained from the U.S. Geological Survey (USGS), Natural Resources Conservation Service (NRCS), Washington State Department of Transportation (WSDOT), Washington State Department of Natural Resources (WSDNR), and Clark County, Washington. Site visits were performed on January 17, 2008 and June 26, 2008. No subsurface investigations were conducted as part of this study.

The area investigated for this report is the SR 502 corridor between NE 15th Avenue and NE 102nd Avenue in Clark County, Washington. The Mill Creek North potential mitigation site and the Sunset Oaks wetland mitigation site were also investigated for this report. The geologic and soils resources potentially affected by the project were identified based on a review of maps, technical reports, and databases available from USGS, NRCS, WSDOT, WSDNR, and Clark County, Washington. Geologic hazards and critical/sensitive areas were identified using Clark County, Washington's Geographic Information System Data. A Conceptual Geotechnical Engineering Recommendations Memorandum prepared by WSDOT (2008), which included previously completed geotechnical borehole data and testing results, was reviewed. Potential effects of the project were determined from preliminary design information and existing conditions of geologic and soils resources in the areas where disturbances would occur.

The study area for this report is defined as the area within unincorporated Clark County along SR 502 beginning at NE 15th Avenue and continuing east to NE 102nd Avenue. The study area is 200 feet north and south from the centerline of the roadway. The Mill Creek North potential mitigation site is included in the study area. A separate area, the Sunset Oaks wetland mitigation site, was studied and included in this report. Hazards that initiate outside of the study areas, such as volcanic eruptions and earthquakes were included in this report.

3.0 Affected Environment

This section describes the affected environment, or existing conditions, within the study area.

3.1 Geologic/Topographic Setting

The study area is located within the Puget-Willamette Lowlands province, which extends from the United States-Canadian border into west-central Oregon, between the Coast Ranges and the Cascade Range. The study area is within a portion of the Puget-Willamette Lowlands known as the Portland Basin. The Portland Basin is a topographic and structural depression formed by volcanic and marine sedimentary rocks of Eocene to Miocene age. Overlying the bedrock are thick sequences of glacial flood and alluvial deposits dating to Miocene age (McFarland and Morgan, 1996 and Evarts, 2004).

The study area is characterized by plains and gently rolling alluvial terraces. The elevation at the west end of the study area is approximately 270 feet above mean sea level (msl). Proceeding east through gently rolling terrain a maximum elevation of 280 feet msl is reached before steadily decreasing to elevation 190 feet msl at Manor Trough (see Exhibit 1), a topographic depression which forms the headwaters of Mill Creek North, and includes Mill Creek draining to the south. Continuing east from Manor Trough the elevation increases through gently rolling terrain to an elevation of 270 feet msl at the east project terminus.

The Sunset Oaks wetland mitigation site is comprised of flat wetlands. The elevation ranges from 188 feet msl to 210 feet msl. The bulk of the site is at approximately 190 feet msl with the western edge of the site sloping to slightly higher elevations.

The surface and near surface geology in the study area is primarily catastrophic flood deposits of silty medium to very fine sand. These deposits have been ascribed to temporary ponding of enormous floods, which resulted from repeated ice dam failures from glacial Lake Missoula, during the Pleistocene epoch to as recently as 13,000 years ago (Howard, 2002). An alluvial fan of gravel from the Troutdale Formation, a unit of weakly consolidated nonmarine sedimentary rocks, is mapped at Manor Trough. The geology of the study area is displayed in Exhibit 1. The surface geology of the Sunset Oaks wetland mitigation site is comprised of fine grained and coarse grained catastrophic flood deposits, which is displayed in Exhibit 2

There are no unique or distinct geologic features in the area potentially affected by the project, including the Sunset Oaks wetland mitigation site. The study area from Manor Trough to the eastern terminus has been identified as a speculative resource of aggregate by the WSDNR. Speculative resources are aggregate resources for which geologic and production information is sparse and where rock types have not been evaluated for their aggregate potential. Nevertheless, inferences can be made from existing geologic mapping and data to suggest that these rock units may have the potential for meeting the threshold criteria established for this study, and possibly containing future aggregate resources (Johnson, et al., 2005).

The Sunset Oaks wetland mitigation site is partially located in an area that has been identified as a gravel aggregate resource, which may contain economic, marginally economic, or sub-economic components (Johnson, et al., 2005).

Exhibit 1. Geologic Map of Study Area

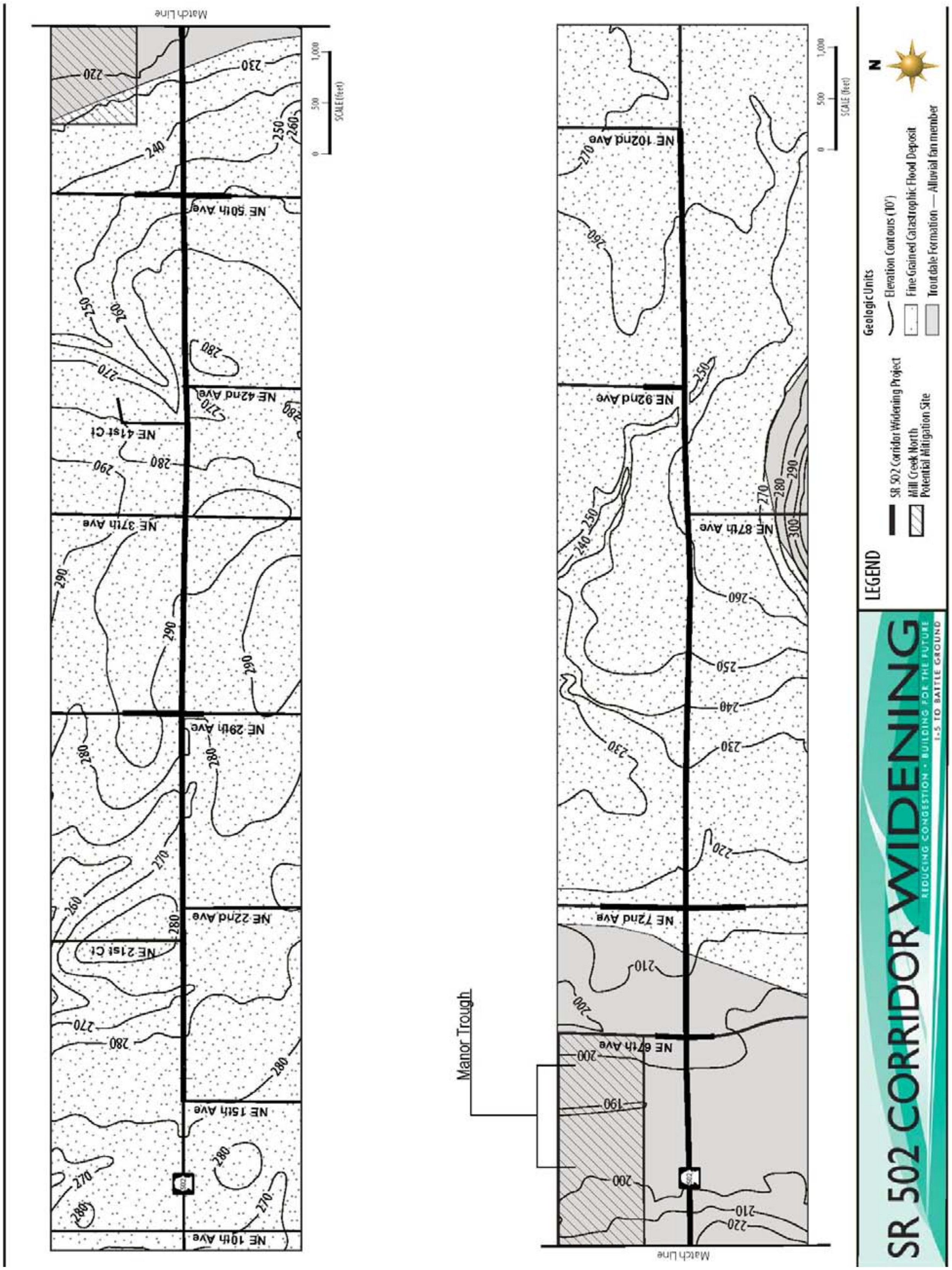
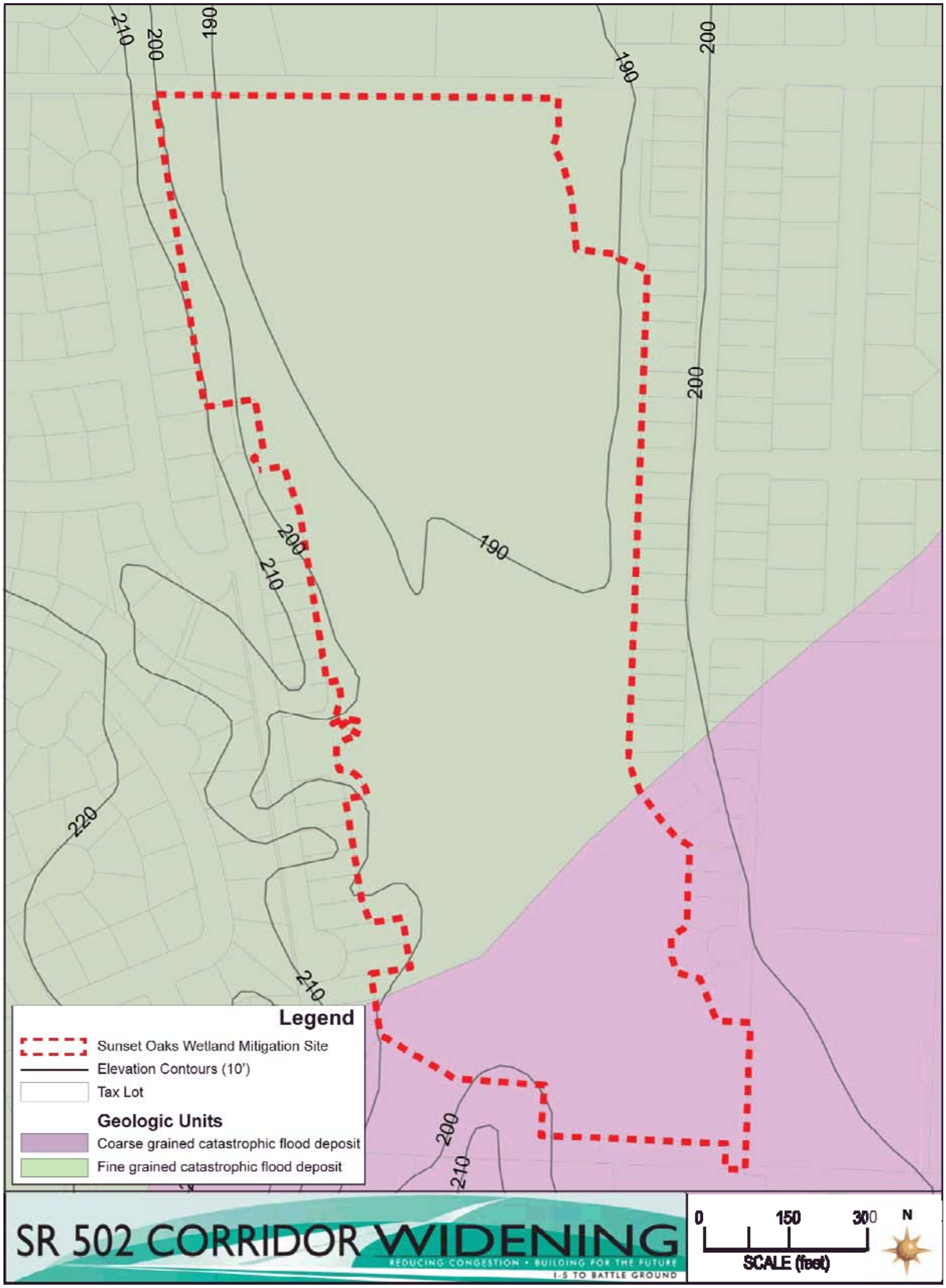


Exhibit 2. Geologic Map of the Sunset Oaks Wetland Mitigation Site.



3.2 Soils

There are 10 soil types within the study area. The mapped areas of the soils within the study area and surrounding vicinity, as identified by the Soil Survey of Clark County, Washington (USDA, 1972), are shown in Exhibit 3. A total of 12 soils are displayed in Exhibit 3, two more than are present in the study area. These two soils, Semiahmoo muck and Hillsboro silt loam, are not present in the study area but are near the project and thus displayed. Brief descriptions of each soil type mapped within the study area are provided in Exhibit 5. Note that the soils described in this section represent the top 5 to 7 feet.

Seven soil types are present within the Sunset Oaks wetland mitigation site (USDA, 1972). These soils are displayed in Exhibit 4 and brief descriptions of each soil type are provided in Exhibit 6. Five of the soil types in the study area have prime farmland soil characteristics: Gee silt loam (0 to 8 percent slopes), Hesson clay loam (0 to 5 percent slopes), Washougal gravelly loam (0 to 8 percent slopes), Lauren loam (0 to 8 percent slopes), and Dollar loam (0 to 5 percent slopes). Two other soils, Tisch silt loam (0 to 3 percent slopes) and Hockinson loam (moderately drained, 0 to 8 percent slopes) would have prime farmland characteristics if drained. Odne silt loam (0 to 5 percent slopes), Cove silty clay loam (0 to 3 percent slopes), and Olequa silty clay loam (20 to 45 percent slopes do not have prime farmland characteristics.

Two of the soil types in the Sunset Oaks wetland mitigation site have prime farmland characteristics: Hillsboro silt loam (0 to 3 percent slopes) and Hillsboro silt loam (3 to 8 percent slopes). McBee silt loam, coarse variant (0 to 3 percent slopes) and Semiahmoo muck, shallow variant (0 to 3 percent slopes) would have prime farmland characteristics if drained while Sifton gravelly loam (0 to 3 percent slopes) would have prime farmland characteristics if irrigated. Two soils, Cove silty clay loam (0 to 3 percent slopes) and Cove silty clay loam, thin solum (0 to 3 percent slopes) do not have prime farmland characteristics.

The Tisch soil series is poorly drained and highly organic, containing peat to a depth of four feet or more. This soil series may be subject to subsidence, the sinking or downward movement of the ground surface, as discussed in the section titled “Subsidence”.

Both the Mill Creek North potential wetland mitigation site and the Sunset Oaks wetland mitigation site contain soils with high organic content and peat, including the Tisch soil series and Semiahmoo muck.

Exhibit 3. Soils Map of Study Area

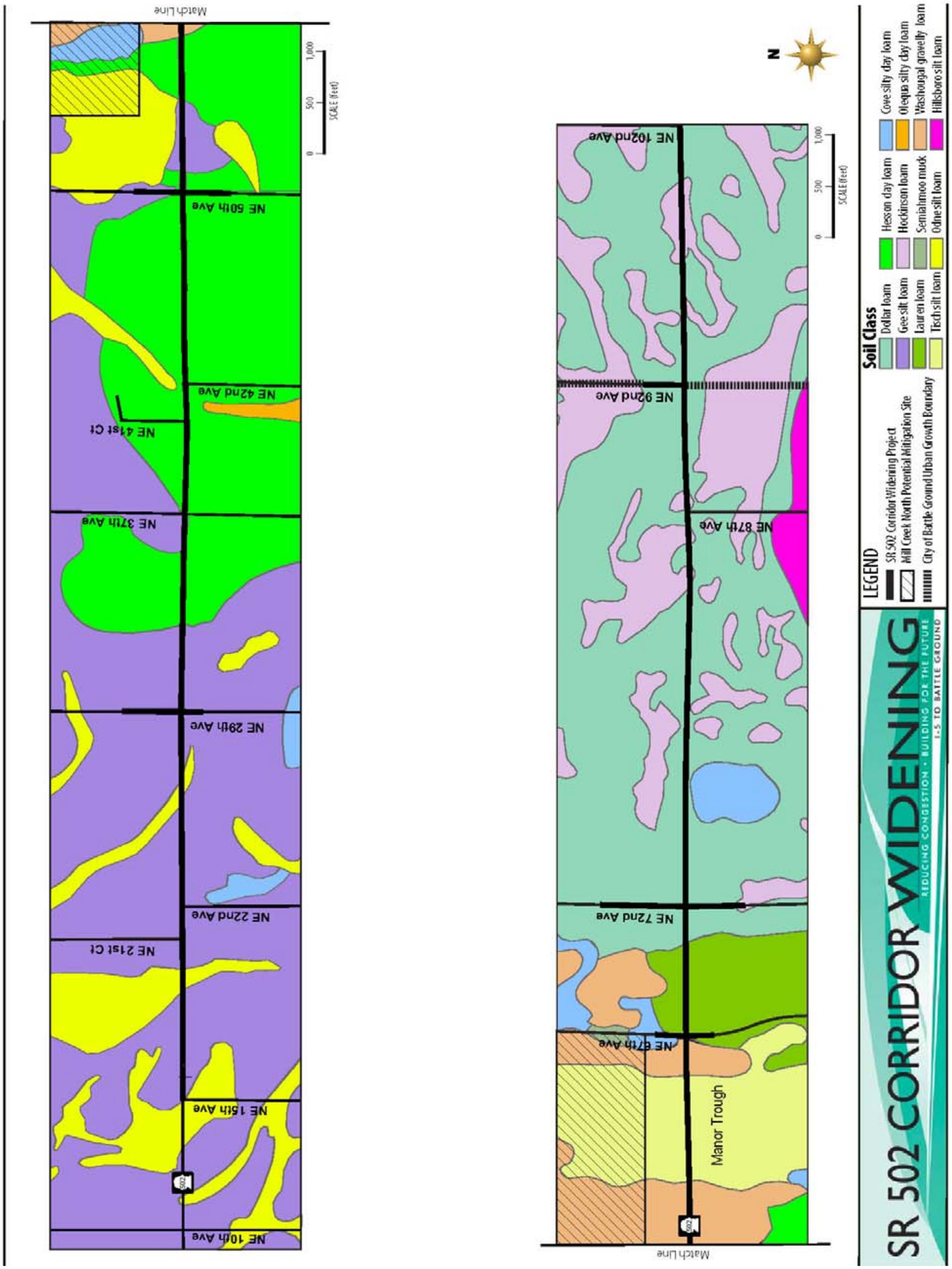


Exhibit 4. Soils Map of the Sunset Oaks Wetland Mitigation Site

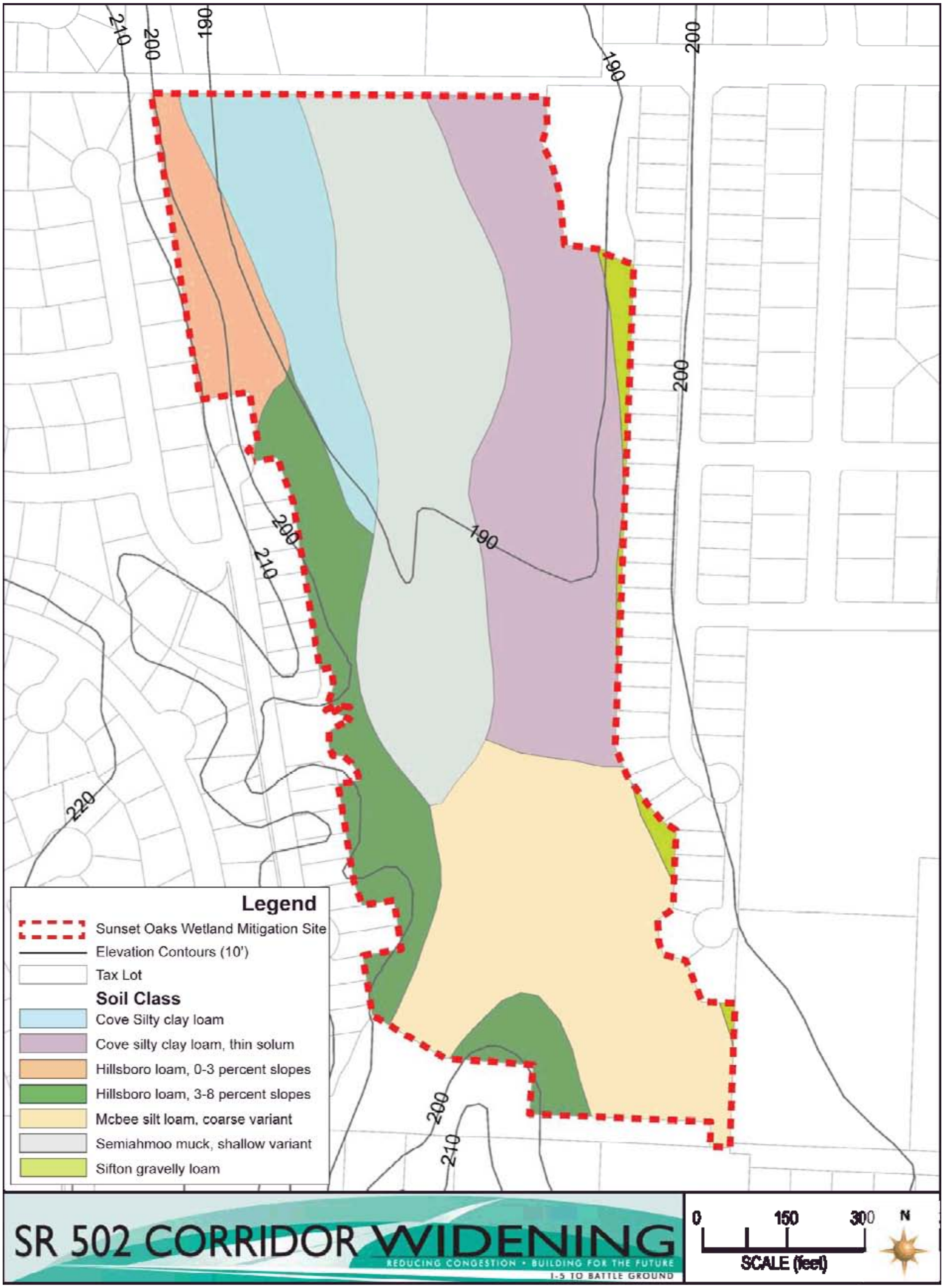


Exhibit 5. Soils Mapped by the USDA within the Study Area as First Encountered from West to East.

Soil Series (Mapping Unit)	Soil Characteristics
Gee silt loam, 0 to 8 percent slopes (GeB)	Deep, moderately well drained soil that occurs on terraces. It was formed by sediments from the Columbia River. Seasonal high water table will develop at a depth of 24 to 48 inches during the rainy season. Surface runoff is slow.
Odne silt loam, 0 to 5 percent slopes (OdB)	Deep, poorly drained soil that occurs in concave areas or depressions within areas of Gee soils. It was formed by sediments of the Columbia River. Seasonal high water table will develop at 0 to 18 inches during the rainy season. Surface runoff is slow to very slow.
Cove silty clay loam, 0 to 3 percent slopes (CvA)	Deep, very poorly drained soil that occurs in concave drainage ways and old lakebeds. It was formed in water-laid deposits in old lakes and ponds. Surface runoff is very slow and will pond in the winter months unless drained.
Hesson clay loam, 0 to 8 percent slopes (HcB)	Deep, well drained soil that is sloped 2 to 5 percent in most places. It was formed by sediments of the Columbia River. Seasonal, perched high water table may develop at 30 to 40 inches.
Olequa silty clay loam, heavy variant, 20 to 45 percent slopes (OhF)	Deep, well-drained soils on terraces above flood plains. It was formed in parent material largely of basic igneous origin. Surface runoff is medium to very rapid.
Washougal gravelly loam, 0 to 8 percent slopes, (WgB)	Well drained soil that was deposited by swiftly flowing rivers and streams and is underlain by sand and gravel. Most of the material is of volcanic origins. It is nearly level except for old, narrow stream channels. Water moves rapidly through this soil.
Tisch silt loam, 0 to 3 percent slopes (ThA)	Deep, poorly drained, highly organic soils that formed in alluvium in shallow depressions. This soil contains peat to a depth of 4 feet or more. This soil is ponded much of the year.
Lauren loam, 0 to 8 percent slopes (LeB)	Deep, well drained gravelly soils that formed in mixed sediments from the Columbia river that contained some volcanic ash. Water moves moderately rapidly through this soil.
Dollar loam, 0 to 5 percent slopes (DoB)	Deep, moderately well drained soil that formed from Columbia River sediments. Seasonal high water table will develop at 18 to 36 inches during the rainy season. Surface runoff is slow.
Hockinson loam, moderately well drained, 0 to 8 percent slopes (HuB)	Deep, moderately well drained soil formed from alluvium of mixed origin. Seasonal high water table will develop at 0 to 18 inches during the rainy season. Surface runoff is slow.

USDA, 1972

Exhibit 6. Soils Mapped by the USDA within the Sunset Oaks Wetland Mitigation Site.

Soil Series (Mapping Unit)	Soil Characteristics
Cove silty clay loam, 0 to 3 percent slopes (CvA)	Deep, very poorly drained soil that occurs in concave drainage ways and old lakebeds. It was formed in water-laid deposits in old lakes and ponds. Surface runoff is very slow and will pond in the winter months unless drained.
Cove silty clay loam, thin solum, 0 to 3 percent slopes (CwA)	Poorly drained soil that occurs in low, wet basins and depression on terraces. Surface runoff is very slow.
Hillsboro silt loam, 0 to 3 percent slopes (HIA)	Deep, well drained soil that occurs on terraces. Surface runoff is very slow.
Hillsboro silt loam, 3 to 8 percent slopes (HIB)	Deep, well drained soil that occurs on terraces. Surface runoff is very slow.
McBee silt loam, coarse variant, 0 to 3 percent slopes (MIA)	Deep, somewhat poorly drained soil in drainageways and depressions. It was formed in alluvium derived from quartzite and basalt. Surface runoff is very slow.
Semiahmoo muck, shallow variant (Su)	Very poorly drained soil that occurs in depressions and basins. It was formed in organic material in low, wet basins or valleys. Surface runoff is very slow to pond.
Sifton gravelly loam, 0 to 3 percent slope (SvA)	Somewhat excessively drained soil that occurs on nearly level to gently sloping terraces. These are gravely soils that formed in alluvial deposits. Surface runoff is very slow.

USDA, 1972

3.3 Geologic Hazards

Geologic hazards that could affect highway development projects include severe erosion areas, high groundwater, landslides, active faults, earthquakes, volcanic activity, and subsidence.

3.3.1 Erosion

Clark County has mapped severe erosion hazard areas within the county. There are no mapped severe erosion hazard areas within the study area or the Sunset Oaks wetland mitigation site (Clark County, 2008). Although no erosion hazards are mapped within the study area, windblown erosion may occur during construction due to the high silt content of the soils.

3.3.2 Groundwater

Groundwater levels in the study area and the Sunset Oaks wetland mitigation site will be near or at the surface for much of the year. A detailed discussion of groundwater is presented in the *Final Water Quality/Surface Water/Floodplains/Groundwater Discipline Report* (Parsons Brinckerhoff, 2008b).

3.3.3 Landslides

Clark County has mapped landslide and steep slope hazard areas within the county. There are no known, reported, or suspected areas of active or historic landslides (including fast-moving landslides and debris flows) in the study area or the Sunset Oaks wetland mitigation site (Brabb, et al., 1999, Clark County, 2008). This was confirmed by the site visit to the study area, during which no evidence of slope instability was found (Parsons Brinckerhoff, 2008e). A site visit to the Sunset Oaks wetland mitigation site found no evidence of slope instability (Parsons Brinckerhoff, 2008d). The USGS identifies most of Clark County, including the study area, as an area of a low landslide incidence, having less than 1.5 percent of the area involved in landslide incidences (Radbruch-Hall, et al., 1982; Godt, 1997).

3.3.4 Seismic

There are no known structural faults in the study area. The closest known fault is the northwest-striking Lacamas Lake fault located approximately seven miles southeast of the study area, and approximately four miles east of the Sunset Oaks wetland mitigation site. The most recent movement of the Lacamas Lake fault is estimated to have occurred in the Middle to late Quaternary period, 750,000 years ago (Personius, 2002).

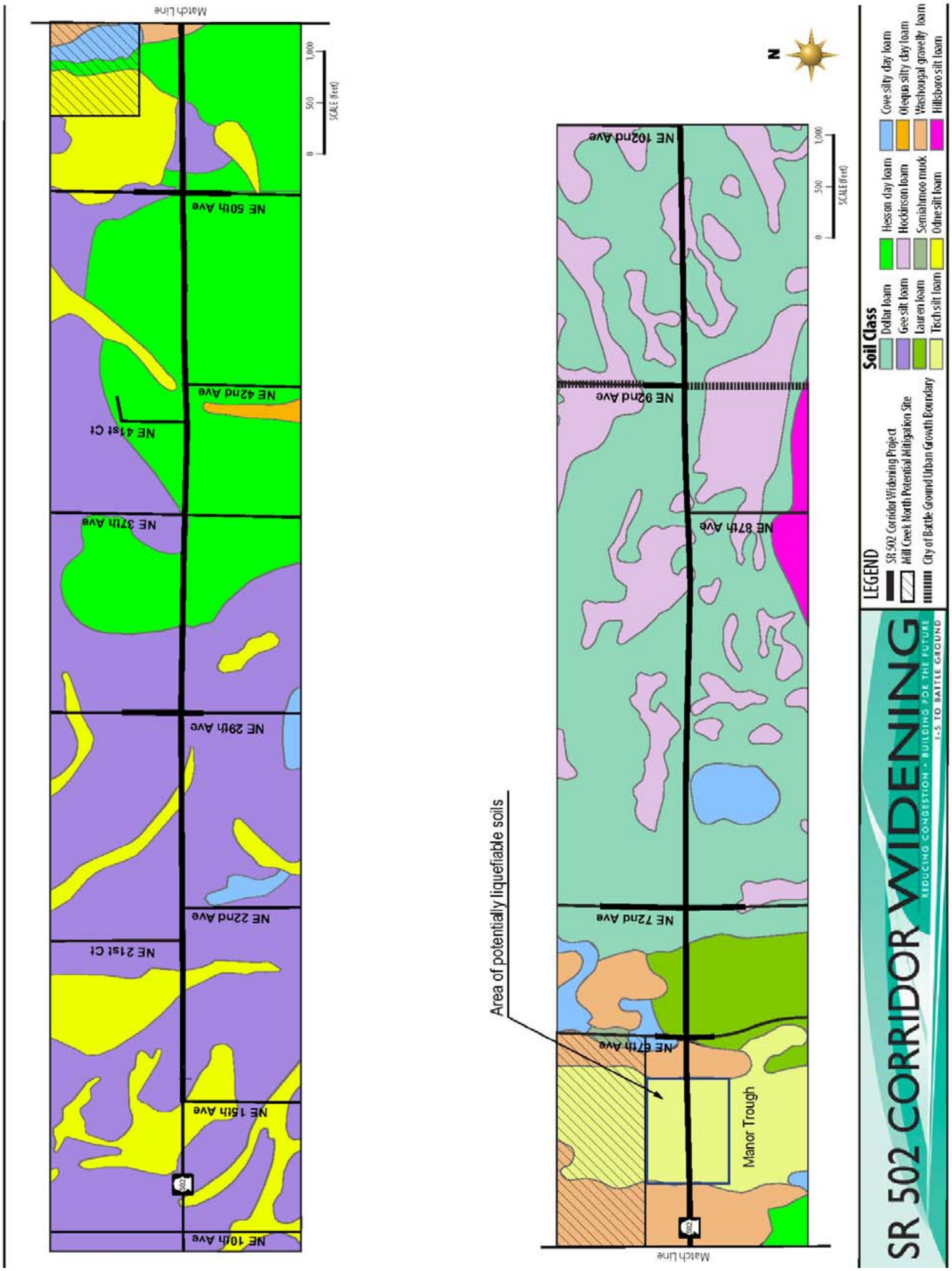
Seismic hazard refers to the probability and amount of ground movement expected from an earthquake. The USGS has produced seismic hazard maps based on seismological, geophysical, and geological information. These maps were developed using a consensus-building process with feedback from geoscientists and engineers.

For a given probability of occurrence, the maps display the most powerful ground motion expected at a location. In the study area, a peak ground acceleration on bedrock of 19 percent gravity (%g) has a 10 percent probability of being exceeded in 50 years (USGS, 2002). This means that over a 50 year period there is a 10 percent chance that an earthquake will produce ground motion exceeding 19 %g at the site. An analysis of ground motion at the Sunset Oaks wetland mitigation site provided accelerations within 0.5 %g of those predicted at the study area (USGS, 2002).

Ground response at a site will differ based on the near surface geology. A site having soft soils will experience stronger shaking than a site on rock. The National Earthquake Hazards Reduction Program (NEHRP) site classes range from A to F, with site class A representing hard rock, B through E representing increasingly softer site conditions, and site class F requiring site specific investigations. NEHRP site class C and D are present in the study area (Clark County, 2008). Two areas of peat (Semiahmoo muck (site class F)) are in close proximity to the study area. The first area is approximately 2000 feet south of SR 502 in Manor Trough at Mill Creek. This area is not mapped on Exhibit 3 because it is outside the study area for this report. The second is approximately 550 feet north of the current SR 502 alignment adjacent to NE 67th Avenue (Palmer, et al., 2004, Clark County, 2008), and is mapped on Exhibit 3 Site class C and D are present at the Sunset Oaks wetland mitigation site. Areas of Semiahmoo muck present at the Sunset Oaks wetland mitigation site are classified as peat (Clark County, 2008).

The WSDNR has classified the susceptibility to liquefaction as “very low” at Manor Trough and “very low to low” at all other locations within the study area (Palmer, et al., 2004, Clark County, 2008). However, geotechnical data from a historic culvert extension project in Manor Trough suggests the upper few feet of alluvium at stream locations would probably liquefy during a strong seismic event (WSDOT, 2008). Soils near existing drainages will likely be non-cohesive and less dense as compared with other soils in Manor Trough, and, therefore, more susceptible to

Exhibit 7. Areas with Potentially Liquefiable Soils



liquefaction. Exhibit 7 displays locations that may be susceptible to liquefaction in the study area.

The Sunset Oaks wetland mitigation site is classified as containing areas with a very low and low to moderate liquefaction risks (Palmer, et al., 2004, Clark County, 2008). The areas classified as low to moderate risk are primarily coarse grained catastrophic flood deposits.

3.3.5 Volcanic

The closest active volcano is Mount St. Helens, located approximately 35 miles northeast of the study area and 40 miles northeast of the Sunset Oaks wetland mitigation site. Based on recent eruptions, the volcanic hazard zone is not considered to extend further than 15 miles south of the crater (Wolfe and Pierson, 1995).

During an eruption, material may be ejected from a volcano and transported through the air. This material is known as tephra and it includes volcanic dust, ash, cinders, pumice, and volcanic blocks, along with other material. The annual probability of accumulation of four or more inches of tephra in the study area or the Sunset Oaks wetland mitigation site is approximately 0.02 percent (Wolfe and Pierson, 1995). This means over a one year period there is a one in 5,000 chance that the study area will be covered by four or more inches of tephra.

3.3.6 Subsidence

Subsidence is the sinking or downward movement of the ground surface. Soils of concern typically include soft and/or organic clay, soft and/or organic silt, and peat. Peaty soils in particular are susceptible to subsidence over a relatively long period of time. Peat within the Tisch soil series has been mapped within Manor Trough (Palmer, et al., 2004, Clark County, 2008). The peat reportedly can experience three to 10 inches of initial subsidence due to drainage of this soil, and up to 60 inches of total subsidence may gradually take place over a period of several years due to a combination of factors (NRCS, 2008). The reported values of subsidence have not been confirmed and no engineering calculations have been performed as part of this report.

The study area was visited on January 17, 2008. The existing SR 502 roadway embankment in the area of Manor Trough appears to have undergone a slight amount of settlement near one of the culverts, causing a noticeable hump in the roadway which may or may not be caused by peat. The pavement in the area appeared to be performing well with no signs of recent maintenance (Parsons Brinckerhoff, 2008d). WSDOT indicates maintenance problems were previously present in the area, however, it is reported there have been no recent maintenance problems in the vicinity (WSDOT, 2008)

A small area mapped as peat along NE 67th Avenue was visited and showed signs of subsidence, including differential settlement of the roadway, pavement rutting, and pavement patching (Parsons Brinckerhoff, 2008d). A large portion of the Sunset Oaks wetland mitigation site is mapped as peat (Semiahmoo muck). Subsidence may occur in peaty areas that are dewatered or subjected to loading.

3.3.7 Abandoned Mines

There is no evidence or knowledge of abandoned mines in the study area or the Sunset Oaks wetland mitigation site (WSDNR, 2004, McKay, et al., 2001).

4.0 Effects and Benefits

This section identifies potential effects and benefits to soils and geology conditions associated with the No Build Alternative and the Build Alternative. Effects and benefits are discussed in terms of temporary effects associated with construction activities, and long-term effects associated with the operation and maintenance of the facility or permanent changes resulting from the project. Indirect and cumulative effects of the project are documented in a separate report, *Indirect Effects and Cumulative Effects Discipline Report.*

4.1 Temporary Effects and Benefits

4.1.1 No Build Alternative

Under the No Build Alternative no improvements would be made to SR 502, therefore no temporary effects or benefits would occur.

4.1.2 Build Alternative

Ground-clearing activities to facilitate construction would have the temporary effect of exposing soils to erosive forces, both from water and wind. Soil loss from erosion could adversely affect surface water resources and associated habitat. Soils exposed to windblown erosion could create nuisance dust, which may reduce visibility, create respiratory hazards, affect adjacent fragile agriculture, and affect the study area aesthetics.

Ground clearing activities could encounter groundwater, especially during the wet season. Soils will be susceptible to disturbance from construction equipment if high groundwater is encountered or during wet weather.

4.2 Long-Term Effects and Benefits

4.2.1 No Build Alternative

The proposed SR 502 widening project would not occur; continued use of the existing SR 502 facility and surrounding land would occur. No soils would be disturbed and no prime farmland would be converted to non-agricultural uses.

4.2.2 Build Alternative

Peat-laden soils, if not identified, could pose a significant effect to the Build Alternative. Peat soils can undergo settlement that occurs over many decades. The settlement can be large enough that pavements become unsafe to drive, culverts and other structures fail to work properly, and downdrag loads can be imparted on deep foundations.

Soils may be encountered that have poor bearing capacity and are unsuitable subgrade material when saturated due to high groundwater or wet weather working conditions. The effects to the Build Alternative if this is encountered could include bearing failure, excessive settlement, and poor pavement performance.

Liquefaction could induce settlement, lateral spreading, and/or stability failure. Liquefaction induced settlement can create downdrag on deep foundations, damage shallow foundations and retaining walls, and damage roadways. Liquefaction induced lateral spread can shear shallow and deep foundations, topple retaining walls, and damage embankments. Liquefaction-induced instability could cause embankment failures that extend into the active travel lanes.

At the current level of design, approximately 12-16 acres of prime agricultural soils would be converted to non-agricultural uses under the Build Alternative. This estimate does not include land that would be used for stormwater detention outside of the right of way or wetland mitigation sites.

Under the Build Alternative, the Mill Creek North potential mitigation site and/or the Sunset Oaks wetland mitigation site may be used to enhance or create wetlands. No adverse effects would be encountered as a result of this action.

5.0 Mitigation

This section discusses potential mitigation measures that could be used to avoid or minimize effects to soils and geology. Potential mitigation measures are discussed for the temporary effects and the long-term effects of the Build Alternative only.

5.1 Mitigation for Temporary Effects

Effects related to soil erosion would be minimized through best management practices during construction. The construction contractor would be required to prepare and implement a Temporary Erosion and Sedimentation Control (TESC) plan prior to construction. The plan would include measures to reduce erosion of exposed soils, excavated material, and fill material. The contractor would also be required to implement dust control during construction.

Effects related to high groundwater and wet weather working conditions would be minimized through the inclusion of Special Provisions for construction delays for weather, excavation in wet soil conditions, dewatering when excavating, erosion control, and drainage.

5.2 Mitigation for Long-Term Effects

Long term effects such as subsidence and liquefaction will be adequately addressed if the WSDOT Geotechnical Design Manual is followed and a proper geotechnical investigation is performed. Poor subgrade materials can also be addressed by following the WSDOT Geotechnical Design Manual. Sections of the WSDOT Geotechnical Manual that address these effects include, but are not limited to, Section 5.9.2 – Peat/Organic Soils, 6.5.2 – Liquefaction, 9.2.4 – Embankment Settlement Assessment, 9.3 – Stability Mitigation, 9.4 – Settlement Mitigation, 11 – Ground Improvement, 16 – Geosynthetic Design, and 17.4 – Culverts. Additionally, by following the applicable WSDOT maintenance procedures for the new facility, long-term effects from operation and maintenance of the facility would be minimized.

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7.0 Glossary

Alluvial deposit	Soil or rock deposited by running water.
Differential settlement	The uneven settlement or downward movement of the ground.
Downdrag	The development of a downward force from soil on a deep foundation, often occurring after soil has liquefied.
Erosion	The wearing away of soil and rock. This may be by weathering and the action of streams, glaciers, waves, wind, and underground water.
Fault	A fracture or fracture zone along with there has been displacement of the sides relative to one another.
Lateral spreading	A liquefaction phenomenon in which incremental horizontal displacement of soil occurs during an earthquake.
Liquefaction	A process in which water-saturated soil temporarily loses its strength and acts as a fluid.
Marine sedimentary rock	A layered rock resulting from the consolidation of sediment in a marine environment.
Peat	A soil formed of decomposing plant material in a water saturated environment.
Prime farmland	A category of protected and highly productive cropland that is recognized by the U.S. Department of Agriculture's Natural Resources Conservation Service.
Seismic hazard	refers to the probability and amount of ground movement expected from an earthquake
Subsidence	The sinking or downward movement of the ground surface.
Tephra	Any material ejected from a volcano during an eruption and transported through the air. This includes volcanic dust, ash, cinders, lapilli, scoria, pumice, bombs, and blocks.
Volcanic rock	Igneous rock resulting from volcanic action near the earth's surface, either ejected explosively or extruded as lava.